

# HPCBS

## High Performance Commercial Building Systems

### **Investigation of the Persistence of New Building Commissioning**

*Element 5*

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## Investigation of the Persistence of New Building Commissioning

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# **Investigation of the Persistence of New Building Commissioning**

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## **Abstract**

Commissioning is gaining increasing recognition as a cost-effective strategy for reducing commercial building energy use. Although the success and cost-effectiveness of commissioning projects depends on how well the benefits of commissioning persist over time, this aspect of commissioning is not well understood.

The persistence of commissioning benefits was recently studied in a PIER project evaluating ten buildings that were commissioned at building start-up at least two years ago. The researchers examined the commissioning reports, control algorithms, EMCS point measurements, and energy use data, and conducted operator and commissioning provider interviews to investigate the persistence of commissioning benefits. In addition, they conducted site visits in a sample of the buildings. A set of commissioning measures was selected for each building to compare the persistence of benefits. Persistence was measured both qualitatively through a discussion of occupant comfort and decreased maintenance and quantitatively through estimations of energy savings.

This paper reports the results of the study. The discussion includes how well the benefits of commissioning persisted over time, reasons for declining performance, and methods for improving persistence. The results provide valuable insight into how to estimate the persistence of commissioning information central to the cost benefit analyses routinely performed for commissioning measures.

## **Introduction**

Complex building systems are becoming more prevalent in commercial buildings, yet building owners often find that their buildings do not operate at the expected level of performance. Several factors contribute to this lack of building performance. The building industry has become increasingly segmented between the trades, and building industry professionals have been forced to reduce their fees to compete in the prevailing low-bid environment. As a result, quality control mechanisms and building system documentation have been largely eliminated from the building development process and installation and operational problems have become commonplace.

More and more building owners commission their buildings to ensure that their new building begins its life cycle at optimal productivity and to improve the likelihood that the equipment will maintain this level of performance throughout its life. Commissioning is a systematic process of ensuring that all building systems perform interactively according to the documented design intent and the owner's operational needs (PECI, 1997). Building commissioning prevents problems from developing, anticipates and regulates system interactions, and implements a systematic method of meeting the building's mechanical, electrical and control requirements. In correcting building performance problems, commissioning reduces repair and replacement costs, employee absenteeism, indoor air quality problems and liability and tenant turnover costs.

The fledgling commissioning industry, though growing every year, must resolve several issues to achieve greater penetration in the building industry and receive further support from utility energy efficiency programs. One of the industry's issues relates to how well the measures that were fixed during commissioning persist over time. In fall of 2001, a Public Interest Energy Research (PIER) project studying five buildings in California and five buildings in the Pacific Northwest that were commissioned at building start-up was undertaken to address the persistence of benefits of commissioning. This study draws qualitative conclusions about the persistence of new building commissioning, focusing on three issues: how well the benefits of commissioning persist, the reasons for declining performance, and the methods that can be used to improve the persistence of benefits achieved through commissioning. A quantitative assessment of persistence by measure ("this measure has an expected persistence of X years") is outside the scope of this project. While this information is desirable for cost-benefit analysis, a larger sample size of buildings would be required.

The Energy Systems Lab conducted the only previous study on the persistence of commissioning benefits. Researchers studied the persistence of existing building commissioning efforts at ten buildings on the Texas A&M campus, and they found a 17% increase in energy use over a period of two years (Turner et.al., 2002). At these buildings, electricity, chilled water, and steam use is metered hourly, which provided a sound basis for calibrated simulation and evaluation of savings degradation.

## **Methodology**

To study the persistence of new building commissioning, we performed the steps listed below. The description that follows provides details about each of these steps.

- Solicit and select buildings to participate
- Select measures to study from the commissioning documentation
- Define criteria for persistence
- Conduct interviews
- Perform site visits for selected buildings
- Determine reasons for persistence and methods for improving persistence

### *Solicit and Select Buildings*

The solicitation and selection of buildings for the study began with calls to owners and government representatives who were known to have had their building commissioned during construction. After these leads turned out to be insufficient in locating buildings, we contacted commissioning providers and California utilities that had commissioning incentive programs.

To qualify for the study, the facility had to be commissioned as a new building or major retrofit between two and eight years ago. Also, the building must have had adequate documentation of measures fixed as a result of commissioning. Since buildings commissioned in California at least two years ago with commissioning documentation were very difficult to find, we selected five buildings in the Pacific Northwest and five buildings in California. We selected the buildings with the most complete commissioning documentation and detailed commissioning

process that we were able to find. Since it was not feasible to find buildings that followed commissioning practices being promulgated by the Building Commissioning Association (BCA, 1999), we studied the persistence of the best commissioning projects we could find.

### *Select Measures*

For each building, we reviewed as much information as possible from the commissioning documentation, and we searched for items that were documented to be fixed during commissioning. The changes and repairs made during commissioning generally fell into three categories: hardware, control system, and documentation improvements. With a main focus on energy saving measures in this study, our first priority for studying persistence was to select the hardware and control system changes with the greatest energy implications.

Not all of the selected measures directly involved energy. Commissioning measures that improved comfort or reliability have significant benefits to the owner and were possibilities for selection.

As we reviewed the commissioning documentation, the driving force behind the selection of measures was the amount of information available about each measure fixed. We could select only measures that were implemented as a part of the commissioning process and included some detail about how the problems were fixed. Many measures were eliminated from potential study because the measures lacked information in the commissioning documentation that would allow us to compare the current operation to the as-commissioned operation. A large number of measures were reported as “recommendations” or “pending” and were not selected.

With a limited budget, we selected measures to maximize the value of the study results. Maintenance issues such as typical calibration errors and clogged filters were not studied because the persistence of these items depend more on routine maintenance than the benefits of the original commissioning process. Due to limited site visit and interview time, we did not place high priority on checking hardware measures that are fairly static once they are fixed (i.e., equipment that was connected to the power supply during commissioning), since these measures are likely to persist. Finally, we did not include changes that resulted from design review, since only one building underwent design phase commissioning. The study focuses on controls sequences, rather than the static hardware and design phase fixes, because the persistence of controls changes are not well understood. Excluding some “sure fixes” will underestimate the overall persistence of commissioning benefits. The act of choosing measures that were feasible to investigate in the time available at each building adds additional measure selection bias. For example, we could not evaluate discharge air temperature cycling during cooling operation in early spring, when the building was not calling for cooling. Due to the selection bias, we present the results of this study in a qualitative manner.

### *Define Persistence*

Before the persistence of the benefits of commissioning for new construction can be determined, we need to understand what it means for a measure to persist. In most cases, persistence or lack of persistence is clear. But some measures may not persist in exactly the way they were initially fixed if they were changed to meet real operating conditions. As long as the measures result in better performance than the pre-commissioning condition, then we define the measure to have

persisted. In some cases, determining the persistence of a measure was inherently subjective, since this involved judging whether the changes build upon and improve the commissioning fix or reduce its effectiveness.

### *Conduct Interviews*

For each building selected, the person from the facilities staff with the most knowledge about the control system was interviewed. The first interview focused on developing an understanding of the commissioning documentation available, the building renovation and occupant history, and the control system. To investigate the commissioning measures in detail, we selected six buildings for site visits. In the remainder of the buildings, we performed a second interview to discuss the current state of selected measures that were fixed during commissioning. The interviews and site visits gave us valuable insight about the reasons for persistence and the methods for improving persistence.

### *Perform Site Visits*

Given the limited budget of the study, we were able to visit six of the ten buildings for approximately a half-day each. At each site visit, we examined the commissioning documentation, system drawings, O&M manuals, and training opportunities at all sites to help understand the resources available to the operations staff. We investigated the persistence of between three and nine specific measures that were fixed during commissioning at each building. While gaining an understanding of the current state of system operation and documentation, we considered the environment that the facilities staff operates under all factors directly related to the persistence of benefits of commissioning.

## **Results**

The results of this study can be broken into two categories: findings due to the difficulties in performing the study, and findings due to studying the building operation. This section presents reasons why buildings were difficult to locate and states the persistence of specific measures at each facility.

### *Difficulty Finding Buildings*

Finding buildings in California that qualified for the study was a long and difficult process. The first California contacts were made in August 2001, but all the buildings were not found until March 2002. Forty-seven building contacts were made in California, resulting in only five California buildings participating. In contrast, the five buildings in Oregon were found to participate in the study with only twelve building contacts made. It may have been easier to find commissioned buildings in Oregon because there is a longer history of new building commissioning in the Pacific Northwest, relative to other parts of the U.S. With the small sample size of buildings in each state, we cannot determine if the overall commissioning process or persistence of benefits differ by state.

Through our efforts, we identified several reasons that California buildings were difficult to locate. First, commissioning summary reports often were not written. Second, if the reports were written, they were not available. Third, new building commissioning does not seem to be as prevalent as retrocommissioning in California 2–7 years ago. Last, many potential measures

listed in the commissioning reports could not be investigated because they were only recommendations and not implemented during commissioning. These four reasons are expanded upon below.

From discussions with commissioning providers, we found that owners often do not pay for the extra effort required to summarize the commissioning findings. Therefore, the volumes of information produced through commissioning are sometimes not put in a form that is usable for facilities staff to better understand their HVAC systems. With limited commissioning budgets, owners may wish to pay for additional functional testing and troubleshooting services rather than a report. One common format for the commissioning documentation was a series of memos (or ‘punchlists’) that periodically updated items for the contractors to fix. As these problems were fixed and removed from the list, the details of the changes most often were not documented.

Even if the reports exist, owners and facility managers often do not have access to them. Commissioning documentation is typically filed away in storage, unavailable, and not organized for easy reference. Commissioning providers, utility representatives, and building staff that have access to these large volumes of documentation did not have sufficient incentive to spend the amount of time necessary to sort through documentation that was not summarized. Six buildings we contacted that had gone through the commissioning process did not have any commissioning documentation available, and therefore, they could not be included in the study.

Through our solicitation of building, it seems that commissioning in California has focused on existing buildings, for the classic reason that owners do not want to pay extra for something they should already be receiving with new construction: well-functioning systems. A number of utility programs in California have focused on retrocommissioning in the past, which directed the enthusiasm for commissioning towards existing buildings.

Commissioning ideally results in a fully operational building, but often in reality, a number of problems remain after commissioning is formally completed. We found that many items in the commissioning documentation had not been resolved, with a number of measures being labeled as "recommendations" or "pending". Problems left unresolved in the formal commissioning process are often expected to be worked out during the first year(s) of operation. Since it is difficult to determine when or if these recommendations were followed, we did not include these fixes as benefits to commissioning.

The lack of commissioning summary documentation and unresolved building problems point to the use of “commissioning” as an umbrella term for a variety of activities. Each commissioning process we encountered was different, as the process must conform to the constraints of each project environment and timeline. Troubleshooting activities and simple checklists were referred to as commissioning, but some of these efforts did not produce enough relevant findings to select the building for the study. As we searched for buildings to participate, commissioning providers and owners told us, “this was not a good example of commissioning” since commissioning was inserted late in the construction process or had a contentious ending. We attempted to select buildings with the most classic commissioning process possible, but it was very difficult to locate these buildings. In effect, we are not studying the persistence of the textbook definition of commissioning, but the variety of ways in which commissioning is implemented in the real world.

## Persistence of Specific Measures

The analysis of the persistence of specific measures is the heart of the study, from which the qualitative conclusions about persistence are drawn. The availability and use of the commissioning report and written sequences of operation were investigated at all sites as a possible factor in ensuring building performance. Figure 1 shows the measures that persisted (light gray square) and did not persist (black square) at each of the ten sites. A square split in half horizontally indicates that more than one measure was investigated in the category.

BUILDING (year commissioned)		DOCUMENTS			CENTRAL PLANT			AIR HANDLING AND DISTRIBUTION								PREFUNCTIONAL TEST				OTHER				
		Commissioning report on site	Commissioning report used	Control sequences available	Chiller control	Cooling tower control	Boiler control	Hydronic control	Economizer control algorithm	Discharge air temperature reset	Simultaneous heating and cooling	VFD modulation	Dessicant cooling	Duct static pressure	Space temperature control	Terminal units	Piping and fitting problems	Valve modification	Wiring and instrumentation	Sensor placement or addition	Sensor error or failure	Scheduling	Skylight louver operation	Occupancy sensor
California	Lab and Office 1 (1995)	no	-	yes																				
	Office Building 1 (1996)	no	-	yes																				
	Office Building 2 (1996)	no	-	no																				
	Office Building 3 (1994)	yes	yes	no																				
	Office Buidling 4 (1994)	no	-																					
Pacific Northwest	Office Building 5 (1997)	no	-	yes																				
	Medical Facility 1 (1998)	yes	yes	yes																				
	Medical Facility 2 (1998)	yes	yes	yes																				
	Lab and Office 2 (1997)	no	-	yes																				
	Lab and Office 3 (2000)	no	-	no																				

**Figure 1.** Persistence of equipment and controls fixed during commissioning. (Light gray boxes show measures that persisted and black boxes show measures that did not persist.)

Across the ten buildings studied, patterns about the types of commissioning fixes that persist emerged. For the measures selected, well over half of commissioning fixes persisted. It is not surprising that hardware fixes, such as moving a sensor or adding a valve, did persist. Furthermore, when control algorithm changes are reprogrammed, these fixes often persisted, especially when comfort was not compromised. We suspect that many design phase fixes may persist in a similar way, but we were not able to study this issue since only one building was commissioned in the design phase.

The types of measures that tended not to persist were the control strategies that can be easily changed, such as occupancy schedules, reset schedules, and chiller staging. Four out of six occupancy scheduling measures did not persist. Chiller control strategies did not persist in three out of four cases, most likely due to the complex nature of control in chilled water systems. We limited our study of sensor issues to major sensor problems that were corrected during commissioning, such as sensor failure or excessively faulty readings. With this selection bias applied, two out of five sensor repairs did not persist.

Although some of the new or “exotic” technologies did not have documented commissioning repairs and thus were not selected for the study, it became apparent during the site visits that these measures tended to have problems. For example, evaporative cooling was disabled, demand control ventilation was not maintained, dimmable ballasts failed prematurely, desiccant cooling failed, and a natural ventilation cycle was problematic. Operator training for these new technologies, while critical, was severely lacking. Operators were not trained in the proper control sequences and maintenance procedures for these systems.

Almost every operator we interviewed stressed that design problems continue to require their attention. Nine of the buildings did not undergo design phase commissioning, and the commissioning provider was forced to work around these problems after construction was completed. Regardless of whether the design problems were fixed during commissioning, these problems are significant to persistence because operators that constantly battle design problems have less time to troubleshoot the performance of the rest of the building. The operators were aware of the lack of design phase commissioning and expressed that these problems should have been caught during a design review process.

## **Discussion**

The findings on the persistence of the measures studied, coupled with an understanding of the operating environment at each building, point to overall reasons for declining or persisting performance and methods for improving persistence. These issues are discussed below.

### **Reasons for Declining Performance**

Through this investigation, we identified three main reasons that benefits of commissioning did not persist: limited operator support and high operator turnover rates, poor information transfer from the commissioning process, and a lack of systems put in place to help operators track performance.

First, many of the operators we interviewed did not have adequate budgets or management support for maintaining their building. This support includes training on the intended system operation and control sequences, the time to proactively assess building operation, and guidance for and motivation to assess energy use. High operator turnover was a major factor in the lack of knowledge about the intended system operation. Operators became more knowledgeable about the operation of their systems when they were involved in the commissioning process, and when these operators leave, the knowledge is often lost. In general, a new operator’s training consisted of about a day walk-through with the former operator. In some cases, training for operators after the commissioning process was completed was inadequate. At one building, plans for recommissioning a lighting system were provided with the commissioning report, but the operators were never trained on how to maintain this system.

Information transfer from the commissioning process to building operation ideally occurs through the systems and commissioning documentation, as well as operator training. In almost every case, it was difficult to locate the commissioning report. For the sites selected, seven out of ten reports were not available on-site. Many other sites were not selected because the commissioning reports were not available or did not include enough information about the problems that were fixed. Building engineers told us that commissioning focused on the short-term goals of providing a well-functioning building before the contractors leave. The

commissioning documentation was a secondary benefit, but one that has implications for the future operation of the building. If commissioning documentation is not available, there may not be a reference point for how the building should run. For a new owner or operator, this lack of information leads to a reduced understanding of the intended operation, problems with troubleshooting, and ultimately could result in decreased performance. If the systems knowledge gained from the commissioning process is not available to the current operators through documentation or training, the value of commissioning is lessened in the long run. From the site visits and interviews, we found that the original commissioning process had little effect on the current operating environment.

Finally, the complexity of present HVAC and lighting systems requires tracking to understand current performance, but these activities were not established through commissioning or implemented after commissioning. Point histories and other control system data were only viewed to troubleshoot a specific problem, and almost never for performance tracking. It was clear that the operators were too busy responding to comfort complaints, doing routine equipment maintenance, and troubleshooting design problems to assess system efficiency. Given adequate time, it is not clear that the operators would have a plan to assess the performance. The baseline (as-commissioned) energy use was determined at only one building, so typically operators also have to establish this baseline for comparison to the current performance.

Performance tracking begins with the utility bills. While operational problems such off-hour operation and high base load energy consumption can be analyzed from utility bill data, this practice occurred at only one building. In four out of the ten buildings, the building operations staff had been alerted by administration of suspicious changes in energy use, but the operators did not view the utility data directly. In five buildings, the operations staff had no information about energy use.

### *Reasons for Persisting Performance*

The persistence of commissioning benefits was found to be highly dependent on the working environment for building engineers and maintenance staff. A working environment that is supportive of persistence includes adequate operator training, a dedicated operations staff with the time to study and optimize building operation, and an administrative focus on building performance and energy costs. Trained operators were found to be knowledgeable about how the systems are supposed to run and, with adequate time and motivation to study the system operation, these operators evaluated and improved building performance. In five buildings, operators participated in the commissioning process and came away with a good understanding of their systems. In addition, good system documentation served as an important troubleshooting resource for operators. Administrative staff can help enable a good working environment by placing high priority on energy efficient systems and operator training. Only a few of the buildings studied seemed to operate in this environment, and the measures investigated at these facilities clearly had the highest rate of persistence.

Another reason that some measures persisted was because there was no reason to change the measure, and the measure can persist without maintenance. For example, if a controls change did not affect comfort, it most likely was not changed. Additionally, if a controls change was buried in the programming code, most operators would not change it without hiring the controls contractor. Hardware problems, often found during prefunctional tests, also tended to persist.

Items such as repiping or correcting wiring, once addressed, physically become relatively passive elements in the system. Other hardware fixes, such as adding a control valve, also tend to persist because there was no reason to intervene.

### *Five Methods for Improving Persistence*

Through studying the persistence of new building commissioning benefits, the following conclusions were made for ways in which persistence can be improved. These methods were developed with building engineers and operators in mind—the people who have the most control over the persistence of commissioning.

1. **Provide operators with training and support.** Operators need training, time to assess performance, and good system documentation to help ensure that the benefits of commissioning persist over time.
2. **Track performance.** New building commissioning should implement mechanisms to track performance, including what information to track, how often to check it, and the magnitude of deviations to address. Commissioning should include documentation that sets baseline operation and provides training on tracking building energy use and system operation. Commissioning could also provide a re-commissioning plan to aid troubleshooting when deviations from the baseline are detected.
3. **Start commissioning in the design phase to avoid nagging design problems.** The most cost effective benefits of commissioning often occur during the design phase, when changes in design are made on paper, rather than during construction or after construction is complete. These changes would likely have high rates of persistence.
4. **Reduce operator turnover.** The knowledge base of the operator that was involved in commissioning should be valued. If this is not feasible to keep this person on-site, the new operator could work with this experienced operator until they are comfortable with system operation. The experienced operator could also act as a consultant to troubleshooting at the building.
5. **Provide better commissioning documentation, including systems descriptions, design intent, and commissioning results (issues log).** The commissioning report should summarize the benefits and set the baseline performance of the building. It is difficult to understand how well a building is operating if there is no baseline for comparison. If the systems knowledge gained from the commissioning process is not available to the current operators, the value of commissioning is decreased in the long run.

### **Next Steps**

The preceding persistence analysis is based on anecdotal evidence from interviews and site visits, which has provided a sound understanding of the issues involved in persistence. In the next phase of this project, this analysis will be supplemented with quantitative analysis. Using the utility bills, we will create calibrated models of selected buildings. The goal of the simulation is to quantify the degradation in energy performance (normalized for weather and building changes) and correlate the changes in performance with the previous findings on the persistence of measures repaired during commissioning.

## Future Study

As the first study of the persistence of commissioning benefits for new construction, this work has begun to address the reasons for persistence and lack of persistence. From our study of ten buildings, we have been able to generalize the persistence of commissioning at an overview level. For future cost-benefit analyses that estimate the measure life of commissioning repairs (commissioning of measure X in a new building has an expected persistence of Y years), a more involved analysis of the persistence of new building commissioning will be necessary. To do this type of quantitative analysis, a larger sample of buildings should be investigated. The study should attempt to look at all measures that were documented during the commissioning process—an effort that may require analysis during multiple seasons.

A major goal of PIER projects is to bring research ideas into current practice. To put the findings from this study to practical use, a manual of guidelines for improving persistence should be developed. The guidelines would give direction to building engineers and operators that wish to maintain the benefits of the new building commissioning process. The manual could be tested through case studies to examine the effectiveness of the implementation methods. In addition, building engineers and operators could participate in-group training sessions on implementing the guidelines.

The success and cost-effectiveness of commissioning depends on how long the benefits persist. Without a good understanding of how to improve persistence, many benefits of commissioning will be lost. Bridging the gap between new building commissioning and day-to-day operations is a challenge that should continue to be addressed by the commissioning industry.

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